General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.

- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.

- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.

- This document is paginated as submitted by the original source.

- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

Produced by the NASA Center for Aerospace Information (CASI)

Update to the Lightning Probability Forecast Equations at Kennedy Space Center/Cape Canaveral Air Force Station, Florida

Winifred Lambert
ENSCO, Inc/Applied Meteorology Unit
William Roeder
USAF 45th Weather Squadron
321-853-8130 lambert.winnie@ensco.com

The 45th Weather Squadron (45 WS), located at Cape Canaveral Air Force Station (CCAFS) in Florida, provides daily 24-Hour and Weekly Planning Forecasts, both of which include the probability of lightning occurrence. This information is used for general planning of operations at CCAFS and Kennedy Space Center (KSC) and helps the forecasters in determining the possibility of issuing lightning advisories during the day. The current lightning probability forecast is based on a subjective analysis of model and observational data and the output from an objective lightning forecast tool developed by the Applied Meteorology Unit (AMU). The lightning probability forecast tool is a set of logistic regression equations that output a probability of lightning occurrence for the day on KSC/CCAFS during the warm season months of May–September (Lambert et al. 2005). The predictors were selected for each month from a set of skew-T indices, the probability of lighting based on seven Florida peninsula flow regimes, the daily lightning probability, and one-day persistence. The period of record (POR) for the data was the warm seasons in the 15-year period 1989–2003. These equations outperformed several standard forecast methods that were used by forecasters and provided 48% better skill than the previous objective tool, and were transitioned into 45 WS operations in time for the 2005 lightning season.

In an effort to improve the probability forecast further, the 45 WS proposed a second phase to make five modifications to the tool: 1) increase the POR, 2) change the method of determining the daily flow regime, 3) test to find the optimal relative humidity (RH) layer, 4) use a new smoother for the daily lightning climatology curve, and 5) refine the forecast valid area.

1) Increase the POR. The POR was increased by adding data from the 2004–2005 warm seasons. The new 17-year POR would likely produce a more accurate daily lightning climatology and produce more robust statistics in the development of the equations.

2) Change flow regime method. The method of determining the flow regime for the first phase equations followed the procedure outlined in Lericos et al. (2002) that used the average wind direction in the 1000–700 mb layer from the Jacksonville, Tampa, and Miami morning soundings. However, this method failed to classify the flow regime in 44% of the days in the POR. For the second phase, the method was modified to include the average 1000–700 mb wind direction from the morning CCAFS sounding. This decreased the unclassified flow regime days significantly to 12% of the days in the POR.

3) Determine optimal RH Layer. The average RH in the 800–600 mb layer from the CCAFS morning sounding was an important predictor for the first phase equations. This parameter was determined over 30 years ago to be valuable in forecasting convection in the KSC/CCAFS area. It has been used in several studies since that time, but no rigorous attempts had been made to determine if 800–600 mb was truly the optimal layer. Using an iterative process and calculating the correlation of many different layers to the occurrence of lightning, the optimal layer was found to be 825–525 mb.

4) New smoothing function for daily lightning climatology. A ±7-day Gaussian smoother with a scale factor of 3 days was used in the first phase to smooth the warm season daily climatology curve, but it still showed some noisiness. A ±14-day smoother with a 7-day scale factor produced smooth results with no noisiness, which may be closer to the actual climatology. This smoother was used to create the daily lightning probability values.

5) New valid area. The valid area for the lightning forecasts was reduced to include only the 5 n mi warning circles on KSC and CCAFS, eliminating the western portion of the area used in the first phase of the work. This is important as previous work has shown that the climatological occurrence of lightning increases rapidly to the west of KSC/CCAFS. Besides changing the verification of lightning events, this affected the values of the flow regime-based probability of lightning occurrence and the daily probability of lightning occurrence. On average, the values of these predictors decreased 5–10%.

The new data and re-calculated predictors were used in the development of five new logistic regression equations, one for each month in the warm season, through a robust statistical selection and elimination of the candidate predictors. The resulting equations contain four to five predictors each. Their performance was tested against that of the phase-one equations and several other forecast benchmarks. Results from four performance tests indicated that the new equations showed an overall 8% increase in skill over the phase-one equations and larger percentages over several standard forecasting methods. They also show more reliability, an improved ability to distinguish between non-lightning and lightning days, and better accuracy measures and skill scores than the current equations. Given their overall good performance, the 45 WS requested that the new equations be transitioned into operations to replace those developed in the first phase. A report describing the details of this work can be found at http://science.ksc.nasa.gov/amu/final.html.

Given the success of these lightning probability equations, the 45 WS tasked the AMU with a third phase of development. This tool will use the natural transitions found in the daily lightning probability climatology curve to stratify the logistic regression equations, as opposed to the monthly stratification currently used. The transition periods will have individual days categorized as in or out of lightning season. In addition, the tool will be expanded to include October. This third phase version of the tool is projected to be delivered in the warm season of 2009. Future phases of this tool will likely expand the sample size when a sufficient number of additional seasons of data are available. It is expected that new data and new techniques will continue to improve the performance if this tool.

References

Lambert, W. C., M. W. Wheeler, and, W. P. Roeder, 2005: Objective Lightning Forecasting at Kennedy Space Center and Cape Canaveral Air Force Station Using Cloud-to-Ground Lightning Surveillance System Data. Conference on Meteorological Applications of Lightning Data, Amer. Met. Soc., San Diego, CA, 10-14 January 2005, 9 pp.

Lericos, T. P., H. E. Fuelberg, A. I. Watson, and R. L. Holle, 2002: Warm season lightning distributions over the Florida Peninsula as related to synoptic patterns. *Wea. Forecasting*, **17**, 83 – 98.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.
PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
11-05-2007	Conference Paper	May 2006 - May 2007

4. TITLE AND SUBTITLE

Update to the Lightning Probability Forecast Equations at Kennedy Space Center/Cape Canaveral Air Force Station, Florida

5a. CONTRACT NUMBER

NNK06MA70C

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Winifred Lambert
William Roeder

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

ENSCO, Inc.
1980 N. Atlantic Ave Suite 230
Cocoa Beach, FL 32931

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

NASA
John F. Kennedy Space Center
Code KT-C-H
Kennedy Space Center, FL 32899

10. SPONSORING/MONITOR'S ACRONYM(S)

11. SPONSORING/MONITORING REPORT NUMBER

12. DISTRIBUTION/AVAILABILITY STATEMENT

Unclassified, Unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This conference presentation describes the improvement of a set of lightning probability forecast equations that are used by the 45th Weather Squadron forecasters for their daily 1100 UTC (0700 EDT) weather briefing during the warm season months of May-September. This information is used for general scheduling of operations at Cape Canaveral Air Force Station and Kennedy Space Center. Forecasters at the Spaceflight Meteorology Group also make thunderstorm forecasts during Shuttle flight operations. Five modifications were made by the Applied Meteorology Unit: increased the period of record from 15 to 17 years, changed the method of calculating the flow regime of the day, calculated a new optimal layer relative humidity, used a new smoothing technique for the daily climatology, and used a new valid area. The test results indicated that the modified equaitions showed and increase in skill over the current equations, good reliability, and an ability to distinguish between lightning and non-lightning days.

15. SUBJECT TERMS

Lightning, Probability forecast, Weather

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Dr. Francis J. Merceret
U	U	U	UU	2	19b. TELEPHONE NUMBER *(Include area code)* (321) 867-0818